its properties, however long it was thus kept. There is no static condition in heat phenomena: exchange is constant. These facts indicate that light or radiant energy is no more an electromagnetic phenomenon than magnetism is a thermal phenomenon, but that it is one of a distinct order.

That point is inmaterial here, for what I wish to call attention to is the fact that a heated body sets up in the ether such a physical condition that its re-action upon another body brings the latter to a condition similar to the first; that is, it heats it.

IV. The Acoustic Field.— There is another physical field with which all are acquainted, though it has not hitherto been called by that name. I refer to the phenomena of sound. Suppose a bell be struck: sound-waves in air are formed, that travel outwards, and have the same geometrical space relations that other fields have. So long as the medium is uniform, the field is uniform, and the energy of the sound-waves per unit surface and unit time varies inversely as the square of the distance from the source. When such sound-waves fall upon other masses of matter, they are absorbed and reflected. Those that are absorbed set the body in vibratory motion similar to the original vibrating body; that is to say, they produce sound. If such second body upon which the waves fall happens to have its own vibratory rate in accordance with the time-rate of the incident waves, the effect is cumulative, and the body may be made to visibly as well as audibly vibrate. If not, the vibrations are said to be forced vibrations; but in every case every body in an acoustic field is made to vibrate. Now, there is the same distinction between the vibratory motions of the bell and the air-waves that result from them as there is between heated molecules and the undulations in the ether; but acoustical terminology has not hitherto been so seriously incommoded hy the failure to make the distinction as has been the case with heat phenomena. As sound phenomena are treated as special cases in kinetics, the space within which sound-waves are produced by the vibratory motions of a body may be spoken of as the acoustic field; and here, as in the other three cases, we have the fact that a sounding body sets up in the medium about it such a physical condition as, by its re-action upon another body, brings the latter into a vibratory state like the first.

These various physical relations may be thus generalized: when a mass of matter acts upon the medium that is about it, the latter is thrown into such a physical conditition or state that its re-action upon another body always induces in the second body a state similar to that of the first body. This has a much wider application than most physical laws; for it embraces phenomena in mechanics, heat, light, electricity, and magnetism. A. E. DOLBEAR.

Tufts College, Dec. 21.

The Waters of the Great Salt Lake.

LONG before white men first trod the shores of the Great Salt Lake, strange stories of this inland sea had found their way into the civilized regions of our own land, and even beyond the ocean. The earliest record of the lake was made in 1689 by the traveller, Le Hontan, who relied for his information upon the wild tales told by the Indian tribes of the Mississippi valley. In 1843, however, the lake was visited, its shores explored, and its waters navigated, by Gen. Frémont, of extensive fame. Six years later (1849–50) a fuller survey was made under the personal direction of Capt. Howard Stansbury, U.S.A., whose report, "Expedition to the Valley of the Great Salt Lake," issued at Washington in 1853.

The Great Salt Lake is by far the largest body of water existing in the "Great Basin." Its average length is seventy-five miles; and its width, forty miles. The altitude of the lake is near forty-two hundred feet above sea-level, and the region is declared by geologists to be still rising.

Even a hasty examination of the Salt Lake valley will convince the observer that the present lake is but the shrunken remnant of a vastly larger body of water, which at one time stretched far beyond the limits of the valley. This former sea was a feature of quaternary times, and has been named Lake Bonneville. It extended beyond the Idaho line on the north, invaded Nevada on the west, and closely approached the Arizona boundary on the south. Of this great body, Utah Lake and Sevier Lake, now existing as distinct occurrences in the regions south, were but comparatively small bays. Numerous water-lines are visible along the mountains adjacent to the Salt Lake, the highest of which is about one thousand feet above the present water surface; and the evidence of wave-action along this ancient shore is abundant.

The history of Lake Bonneville, as recorded on the stony pages of its precipitous shores, and in the hardened sediments of its floor, is more complicated than a mere recital of the shrinking and falling of waters through evaporation and other wasting causes. For most of our knowledge upon this subject, we are indebted to the detailed observation and study conducted by the United States Government Survey corps, and especially to the investigations carried on under the direction of Major J. W. Powell. Referring to the labors of Mr. C. K. Gilbert and his associates in the lake region, Director Powell thus briefly summarizes the history of Lake Bonneville: —

"First, the waters were low, occupying, as Great Salt Lake now does, only a limited portion of the bottom of the basin. Then they gradually rose and spread, forming an inland sea, nearly equal to Lake Huron in extent,,with a maximum depth of one thousand feet. Then the waters fell, and the lake not merely dwindled in size, but absolutely disappeared, leaving a plain even more desolate than the Great Salt Lake Desert of to-day. Then they again rose, surpassing even their former height, and eventually overflowing the basin at its northern edge, sending a tributary stream to the Columbia River; and, last, there was a second recession, and the waters shrunk away, until now only Great Salt Lake and two smaller lakes remain."

As is clearly understood, the oscillations of the water in a lake possessing no outlet will be far more marked than in an opposite case. In a body of water with an outflow, a tolerably uniform level will be maintained, the irregularities in the supply being compensated for the most part by the varying volume of water flowing away; but the level of a lake completely enclosed will be due to the relation existing between the supply of water and the rate of evaporation. The topography of the ancient shore-line of the Great Salt Lake shows, that since the time of the "second recession" of the waters, referred to by Major Powell in the quotation made above, the lake has been unable to find an outlet for its contents, and has consequently reached its present diminutive proportions through loss by evaporation alone. The composition of the water would necessarily vary with the concentration. The analysis most commonly accepted, and which forms, indeed, the basis for current quotations and references, is that made by Dr. Gale, and published in Stansbury's report. Gale found the water to possess a specific gravity of 1.170, and to contain 22.282 per cent by weight of solid matter, as follows: sodium chloride ($NaCl$), 20.196 per cent; sodium sulphate (Na_2SO_4), 1.834; magnesium chloride ($MgCl_2$), 0.252; calcium chloride ($CaCl_2$), a trace.

These figures are used as indicative of the present composition in several of the most recent cyclopædias, such as are used for general reference; and even the revised school text-books in geography quote as above. It should be remembered in accepting such results, however, that the investigation upon which they are based was made on water collected forty years ago; and it is scarcely to be expected that such would represent the composition of the water at the present time. For a number of years preceding 1883 the lake had been steadily rising. This rise was entirely independent of the annual oscillations to which the waters of the lake seem subject under all circumstances. In referring to this fact, Mr. Gilbert writes as follows (see "Lands of the Arid Regions," p. 66): —

"Thus it appears that in recent times the lake has overstepped a bound to which it had long been subject. Previous to the year 1865, and for a period of indefinite duration, it rose and fell with the limited oscillation and with the annual tide, but was never carried beyond a certain limiting line. In that year, or the one following, it passed the line, and it has not yet returned. The annual tide and the limited oscillations are continued as before, but the lowest stage of the new *régime* is higher than the highest stage of the old. The mean stage of the new *régime* is seven or eight feet higher than the mean stage of the old. The mean area of the water surface is a sixth part greater under the new *régime* than under the old. The last statement is based on the United States surveys of Capt. Stansbury and Mr. King. The former gathered

the material for his map in 1850, when the water was at its lowest stage, and the latter in the spring of 1869, when the water was near its highest stage. The one map shows an area of 1,750, and the other of 2,166, square miles. From these I estimate the old mean area at 1,820 miles, and the new at 2,125 miles, and the increase at 305 miles, or 17 per cent."

The probable cause of this increased water-supply in the Great Basin would form a most interesting and instructive subject of inquiry, but such would be foreign to the purposes of the present paper; and here it must suffice to say, that two theories have been advanced as offering most probable explanations of the phenomenon; viz., the climatic theory, and the theory of human agencies. In the report already referred to ("Lands of the Arid Regions") the author says, "On the whole, it may be wise to hold the question an open one, whether the water-supply has been increased by a climatic change, or by human agency. So far as we now know, neither theory is inconsistent with the facts, and it is possible that the truth includes both."

During this recent epoch of increasing volume, the lake-water would be naturally expected to show a far lower percentage of solid contents. In "Contributions to the History of Lake Bonneville," published in the "Report of the United States Geological Survey, 1880–81," Gilbert places the total salinity of the water at fifteen per cent, — a striking variation from the figures of Dr. Gale, yet a variation not at all too great to be fully explained by the increased volume of the lake, and the consequent decrease in concentration. An investigation of the water by Allen in 1869 (see King's report) showed the total solid matter to be 14.9934 per cent. The present writer made an analysis on water taken from the lake in December, 1885, with the following results: —

	Grams per Litre.	Per Cent by Weight.
Sodium chloride ($Na\,Cl$)	152.4983	13.5856
Sodium sulphate ($Na_2\,SO_4$)	15.9540	1.4213
Magnesium chloride ($Mg\,Cl_2$)	12.6776	1.1295
Calcium sulphate ($Ca\,SO_4$)	1.6679	0.1477
Potassium sulphate ($K_2\,SO_4$)	4.8503	0.4321
Total solid matter	187.6481	16.7162

This water had a specific gravity of 1.1225. Another sample of lake-water taken in February, 1888, showed a density of 1.1261. A further test was made in June, 1889, the water being 1.148 in density; and in August, 1889, the water was 1.1569. The figures resulting from the latest determinations show a considerable increase in the proportion of solids; and this is fully explained by the succession of excessively dry seasons to which the Great Basin has been subjected since 1883, causing a remarkable shrinking of the lake volume. In August, 1889, the lake was lower than at any time since the inauguration of Gilbert's "new *régime*." A sample of water was taken from the lake during that month, and analyzed, with these results. The water possessed a specific gravity of 1.1569, and contained, —

	Grams per Litre.	Per Cent by Weight.
Sodium chloride ($Na\,Cl$)	182.131	15.7430
Sodium sulphate ($Na_2\,SO_4$)	12.150	1.0502
Magnesium chloride ($Mg\,Cl_2$)	23.270	2.0114
Calcium sulphate ($Ca\,SO_4$)	3.225	.2788
Potassium sulphate ($K_2\,SO_4$)	5.487	.4742
Total solids	226.263	19.5576

It would be a difficult task indeed to determine the mean composition of the lake. Its waters rise and fall, and become more concentrated or dilute, according to the conditions controlling the rates of supply and evaporation. The latest analysis reported above, indicating 19.5576 per cent solid matter, though it is a closer approach than usual to the earliest figures, and the ones most widely published, is hardly to be considered typical, since the season of 1889 was one of unusual drought. Two or three consecutive winters with heavy snows would dilute the water to its condition of a few years ago. In the opinion of the writer, it would be more correct to quote the average contents of the Salt Lake water at sixteen per cent solid matters than at twenty-two per cent, as is most frequently done.

Our subject presents an economical aspect which is well worthy of attentive consideration. The composition of the water is such as to suggest the easy manufacture of a number of chemical substances therefrom. Branches of such an enterprise have already been instituted, and the results achieved have kindled the brightest hopes of increasing success.

The preparation of common salt from the water would be naturally the first undertaking of the kind to suggest itself; and this process has been in successful operation on an industrial scale for a number of years. There are now half a dozen establishments for salt-manufacture on the lake shore. At several of these places, however, the preparations for salt-making consist simply in constructing a number of evaporating-ponds below the level of the lake, and separated from the latter by dikes of such a height that during periods of rough water the waves beat over the embankments, and fill the ponds with brine. The evaporation of the water thus enclosed goes on without any artificial aid, and a bountiful harvest of salt in the season thereof is the result. In such cases the evaporation is carried to completion. All the solid constituents of the brine remain in the salt, there being no attempt made to get rid of the mother-liquors after the deposit of crystals.

At other of the works, however, notably at the Inland Salt Company's Gardens, a different plan is pursued. This establishment is the largest salt-works in the West, and is situated near Garfield Beach, the most popular pleasure-resort on the lake. The method employed by this company differs from those already described in that the water is pumped from the lake into ponds prepared for its reception, and situated above the level of the lake surface. The mother-liquors flow off — are returned to the lake, in fact — when the evaporation has reached the proper stage. From the establishment of the works until 1883 the lake was close to the ponds; but, owing to the unusually high rate of evaporation attending the dry seasons of the immediate past, the water has receded, so that at present it has to be conveyed over 2,500 feet to the evaporating receptacles. This is effected by the aid of two centrifugal pumps, raising together 14,000 gallons of water per minute. The pumps throw the water to a height of fourteen feet, into a flume, through which it flows to the ponds. These are nine in number, and are arranged in series. In the first pond the mechanically suspended matters are left as sediment or scum, and the water passes into the second in a clear condition. The ponds cover upwards of a thousand acres, and the drain channels leading from them aggregate nine miles in length. The pumping continues through May, June, and July. A fair idea of the rate of evaporation in the thirsty atmosphere of the Great Basin may be gained from contemplating the fact that to supply the volume of water disappearing from the ponds by evaporation requires the action of the pumps ten hours daily in June and July. This is equal to the carrying away of 8,400,000 gallons per day from the surface of the ponds.

The "salt harvest" begins in August, soon after the cessation of pumping, and continues till all is gathered, frequently extending into the spring months of the succeeding year. An average season yields a layer of salt seven inches deep, which amount would be deposited from forty-nine inches of lake-water. The density at which salt begins to deposit, as observed at the ponds, and confirmed by laboratory experiments, is 1.2121, and that of the escaping mother-liquors is 1.2345. The yield of salt is at the rate of 150 tons per inch depth per acre. The crop is gathered on horse-cars which run on movable tracks into the ponds. At the works the operations are simple and effective. A link-belt conveyor carries the coarse salt to the crusher, thence to the dryer, after which a sifting process is employed by which the salt is separated into table salt and dairy salt.

It will be seen from the foregoing that the preparation of salt

from the lake-water consists of little more than evaporation and crushing, and the former part of the operation is effected wholly through natural agencies. The simplicity of the process, and the lavish yield, enable the manufacturers to put their commodity on the market at an incredibly low price. The Inland Salt Company sells dry, coarse salt for the Eastern trade, packed on cars at the works, at one dollar per ton.

The quality of the lake-salt is of the highest grade. Several specimens of the commercial article, as manufactured and sold by the various companies, have been analyzed by the writer; and of these, the following are typical: —

	Salt made and sold by the Inland Salt Co.	Salt made and sold by the Jeremy Salt Co.
Sodium chloride (Na Cl)	98.407 per cent	98.300 per cent
Calcium chloride ($CaCl_2$)	.371 " "	.345 " "
Calcium sulphate ($CaSO_4$)	.650 " "	.680 " "
Magnesium sulphate ($MgSO_4$)	.030 " "	.042 " "
Insoluble matters	.102 " "	.472 " "
Moisture	.442 " "	.158 " "
	100.002 " "	99 997 " "

According to published figures, commercial bay salt from other sources seldom exceeds 96 per cent sodium chloride.

Next to common salt, in the order of abundance and ease of preparation, sodium sulphate should be named. This is deposited in the crystallized form as mirabilite (Na $SO_4 + 10 H_2O$) during the winter season. When the temperature falls to a certain point, the lake-water assumes an opalescent appearance from the separation of the sulphate. This sinks as a crystalline precipitate, and much is carried by the waves upon the beach and there deposited. Under favorable circumstances, the shores become covered to a depth of several feet with crystallized mirabilite. The writer has on several occasions waded through such deposits, sinking at every step to the knees. Speaking only of the amounts thrown upon the shores, and of most ready access, the source is practically inexhaustible. The substance must be gathered, if at all, soon after the deposit first appears; as, if the water once rises above the critical temperature, the whole deposit is taken again into solution. This change is very rapid, a single day being oftentimes sufficient to effect the entire disappearance of all the deposit within reach of the waves. Warned by these circumstances, the collectors heap the substance on the shores above the lap of the waters, in which situation it is comparatively secure until needed. To a slight depth the mirabilite effloresces, but within the piles the hydrous crystalline condition is maintained. At the present time there are thousands of tons of this material, heaped in the manner described, remaining from the collections of preceding winters. The sodium sulphate thus lavishly supplied is of a fair degree of purity, as will be seen from the following analyses of two samples of the crystallized substance, taken from opposite shores of the lake: —

	1.	2.
Water (H_2O)	55 070 per cent.	55.760 per cent.
Sodium sulphate (Na_2SO_4)	43.060 " "	42.325 " "
Sodium chloride (Na Cl)	.699 " "	.631 " "
Calcium sulphate ($CaSO_4$)	.407 " "	.267 " "
Magnesium sulphate ($MgSO_4$)	.025 " "	.018 " "
Insoluble	.700 " "	.756 " "
	99.991 " "	99.757 " "

For purposes of easy comparison, it should be added that chemically pure mirabilite ($Na_2SO_4 + 10 H_2O$) consists of 44.1 per cent of sodium sulphate (Na_2SO_4) and 55.9 per cent of water.

Beside such substances as are presented in a comparatively pure form by the lake, the price being simply the labor of collecting, there are many other compounds that may be had for the asking. The unlimited quantities of sodium sulphate spread upon the shore every winter, forcibly suggest the sodium-carbonate industry as a promising undertaking, the chemical labor for preparing the carbonate by the Le Blanc process being, in fact, already half done. A few years ago an establishment was founded for this purpose in Salt Lake City, and, though the labor thus far accomplished has been mostly experimental in its nature, the results conclusively prove that sodium carbonate and a number of other chemical compounds may be derived from the lake-water with ease and profit. When once such manufacture is undertaken on a proper scale, the output of soda need be limited only by the capacity of the works. Caustic soda and sodium hyposulphite have also been prepared from the lake.

The importance of the Great Salt Lake as a source of chemical supplies is still unrealized. Figures would have but little meaning if used in an attempt to express the chemical wealth diffused through its briny waters.

Even for the unscientific observer and the casual visitor, the characteristic phenomena of the lake possess a fascinating interest. Many persons who would be but slightly moved by the statement that the waters of the lake vary in density between 1.12 and 1.17 would be deeply impressed to learn that a bather can float at ease in the water with a large proportion of the body above the surface. When once accustomed to the lake, the swimmer can lie in the watery cradle, with his head resting on a pillow of wood, as securely as in a suspended hammock. The chief difficulty in swimming is the tendency of the lower limbs to rise above the water; and the principal danger lies in the occasional entrance of brine into mouth or nostrils, producing a painful irritation followed by suffocation.

The concentrated state of the brine insures the lake against the fetters of frost. Ice is not to be seen upon its bosom even during the severest winters. The temperature falls at times to —20° F., yet the lake remains as freely open as during the warmer seasons.

The antiseptic properties of the water have been known from the time of its earliest investigation. Capt. Stansbury reported a test, which has been repeatedly verified since his time. His description was as follows: —

"Before leaving Black Rock, we made an experiment upon the properties of the lake for preserving meat. A large piece of fresh beef was suspended by a cord, and immersed in the lake rather more than twelve hours, when it was found to be tolerably well corned. After this, all the beef we wished to preserve while operating upon the lake was packed into barrels, without any salt whatever, and the vessels were then filled up with the lake-water. No further care or preparation was necessary, and the meat kept sweet, although constantly exposed to the sun. I have no doubt that meat put up in this water would remain sound and good as long as if prepared by the most improved methods. Indeed, we were obliged to mix fresh water with this natural brine to prevent our meat from becoming too salt for present use, a very few days' immersion changing its character from corned beef to what the sailors call 'salt junk.'"

As would be expected of so concentrated a brine, and as has been proved by observation, life in the waters of the Great Salt Lake is confined to few species. Some writers have declared that no form of animal or plant life exists in the lake; but this is an error, with but little excuse for its perpetration. The tiny crustacean, *Artemia fertilis*, exists in very great numbers, often tinting the water over wide areas with its own delicate pink. There is also *Ephydra gracilis* in its early stages. The pupa cases of this insect are often carried ashore in large masses, where they undergo decomposition with characteristic odorous emanations. One form of *Corixa* has also been found. No fish or other large form of animal life, however, has been discovered in the waters. The vegetable organisms of the lake, the presence of which may be considered a fact from the abundance of animal existences, are almost entirely unstudied. The life of the Great Salt Lake is a subject awaiting further investigation than has thus far been bestowed thereon.

JAMES E. TALMAGE.

Salt Lake City, Utah, Dec. 11.